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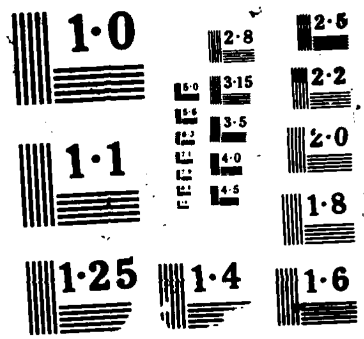
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A user's guide for the analytical photogrammetric positioning system (APPS)

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George E. Newbury

November 1986

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Prepared for

U.S. ARMY CORP OF ENGINEERS
ENGINEER TOPOGRAPHIC LABORATORIES
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The purpose of this report is to describe the Analytical Photogrammetric Positioning System (APPS) and the Automated Geographic Information System (AUTOGIS). The report describes the recommended approach for using the hardware and software, and gives some examples of projects that may make use of the systems.

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PREFACE

This report was prepared under the supervision of A.C. Elser, Chief, Geographic Information Systems Division; and B.K. Opitz, Director, Geographic Sciences Laboratory.

The author wishes to express his appreciation to Mr. Daniel Edwards, who answered many queries concerning the APPS-IV.

Col. Alan L. Laubscher, CE, was the Commander and Director, and Mr. Walter E. Boge was the Technical Director of the Engineer Topographic Laboratories during the report preparation.

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A USER'S GUIDE FOR THE ANALYTICAL PHOTOGRAMMETRIC POSITIONING SYSTEM (APPS)

1.0 Introduction

In any endeavor, it helps to know the past in order to prepare for the future. The Corps of Engineers, as manager of the Nation's waterways, must be able to analyze the past of these waterways in order to manage them in the present and to plan for their future. Aerial photography, dating back to the early 1930's, is one tool available that enables you to analyze past conditions because photos accurately depict physical environment features. The amount of vegetative cover, the location of specific physical features, and many other specific details may be obtained if you analyze aerial photos.

You must integrate the data from old aerial photos with present and future data bases before the data can be effectively used. This integration is made easier by an instrument that enables a professional in the subject matter (engineering, geology, hydrology, etc.) to analyze the imagery and create a topologically valid digital data base. The instrument should be capable of maintaining present day mapping standards and enable one to analyze, store, and present the data digitally. The APPS-IV (Analytical Photogrammetric Positioning System, model IV) is such an instrument.

The purpose of this report is to

1. Describe the APPS-IV and AUTOGIS (Automated Geographic Information System).
2. Describe the recommended approach for using the hardware and software.
3. Give some examples of projects that may use the systems.

1.1 Background

The remote sensing community stores, retrieves, analyzes, manipulates, and displays large quantities of image data. Many new techniques and instruments have been developed to assist the image analyst to exploit this data. The U.S. Army Engineer Topographic Laboratories (ETL) recognized the technological advances in analytical plotters and developed the CAPIR (Computer-Assisted PhotoInterpretation Research) facility to take advantage of, and to advance, the state of the art in this area of technology. The CAPIR facility hardware includes an APPS-IV, an X-Y digitizing table, and a host computer with associated output devices. The software for the system is the Automated Geographic Information System (AUTOGIS) which is programmed in FORTRAN.

ETL conducted work under the Corps' Surveying and Satellite Applications Remote Sensing research program to evaluate, demonstrate and document the potential of APPS-IV CAPIR technology for civil works applications. As part of this effort, a contract (DAAK70-81-C-0261) was awarded to Autometric, Inc., Falls Church, Va., to assess potential civil works and military applications and to plan and conduct experiments to demonstrate possible uses of this technology. The results of this contract included three reports, ETL-0310[1], ETL-0333[2], and ETL-0336[3].

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[1] Johathan C. Howland, *APPS-IV Civil Works Data Extraction Data Base Application Study (Phase II)*, Autometric, Inc., Fassis Church, VA. Prepared for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0310, September 1982, AD-A123 889

[2] James D. Peroutky, *APPS-IV Remote Sensing Applications Guide*, Autometric, Inc., Falls Church, VA. Prepared for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0333, June 1983, AD-A134 977

[3] James D. Peroutky, *APPS-IV Civil Works Data Extraction Data Base Application Study (Phase II)*, Autometric, Inc., Falls Church, VA. Prepared for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0336, September 1983, AD-A134 215

2.0 The APPS-IV and CAPIR System

Three subsystems are associated with the APPS-IV (fig. 1).

1. The stereoplotter.
2. The desk containing most of the electronics.
3. The host computer and peripherals.

The actual system hardware used at the ETL CAPIR facility was configured as follows:

APPS-IV
Data General Eclipse S 250 minicomputer with
  integral array processor
  192 mb disk
  800 bpi tape drive
  1600 bpi tape drive
  CRT
X-Y digitizing table, 36" x 48"

2.1.1 The APPS-IV

The APPS-IV instrument is a medium accuracy (± 10 microns), analytical stereoplotter (fig. 2). It has an optical system for viewing stereo imagery, a mechanical system with a unique stage-on-stage design, and an electronics subsystem with 13 microprocessors. The system is very compact compared to many other medium accuracy analytical stereoplotters.

An INTEL 8085 cpu is included in the electronics subsystem. Having inbedded microprocessors provides the following benefits:

1. 110 points may be entered prior to downloading the data to the host computer, thus allowing the host to perform other functions.
2. Points may be digitized as the operator traces a boundary (rather than dropping nodes).
3. Errors may be corrected more easily.

The 13 microprocessors control servo-motors that drive stage movement and control stereomodel maintenance. They communicate with the host computer via an RS232c interface.

2.1.2 The APPS-IV Stage Controls

The stage controls of the APPS-IV (fig. 3) enable the stages to be moved in the following ways:

1. Manually, with stage disengage button.
2. With a trackball.
3. With thumbwheels.
4. Automatically with the machine moving to a preselected point or along a transect.

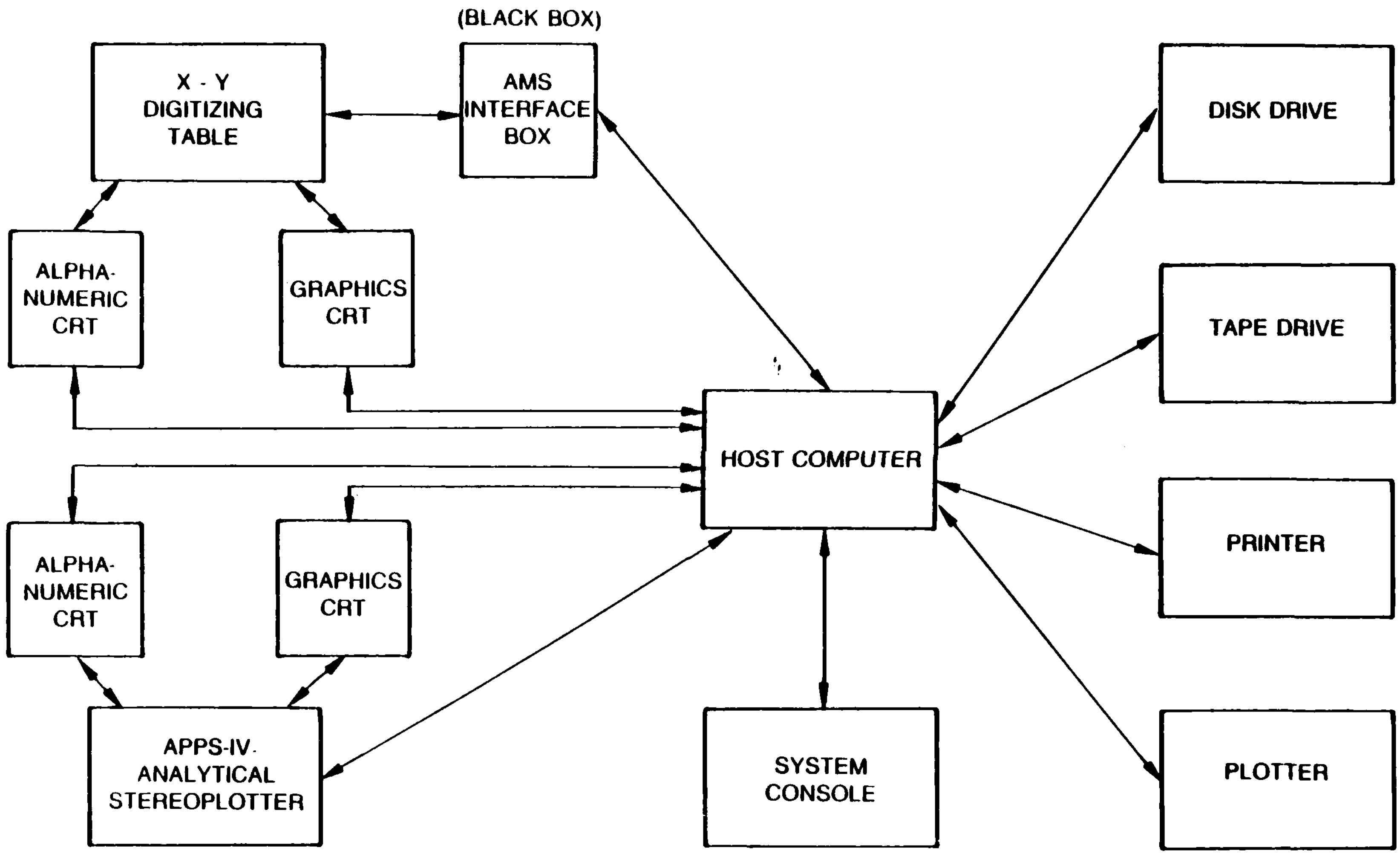


FIGURE 1. Basic CAPIR system components.

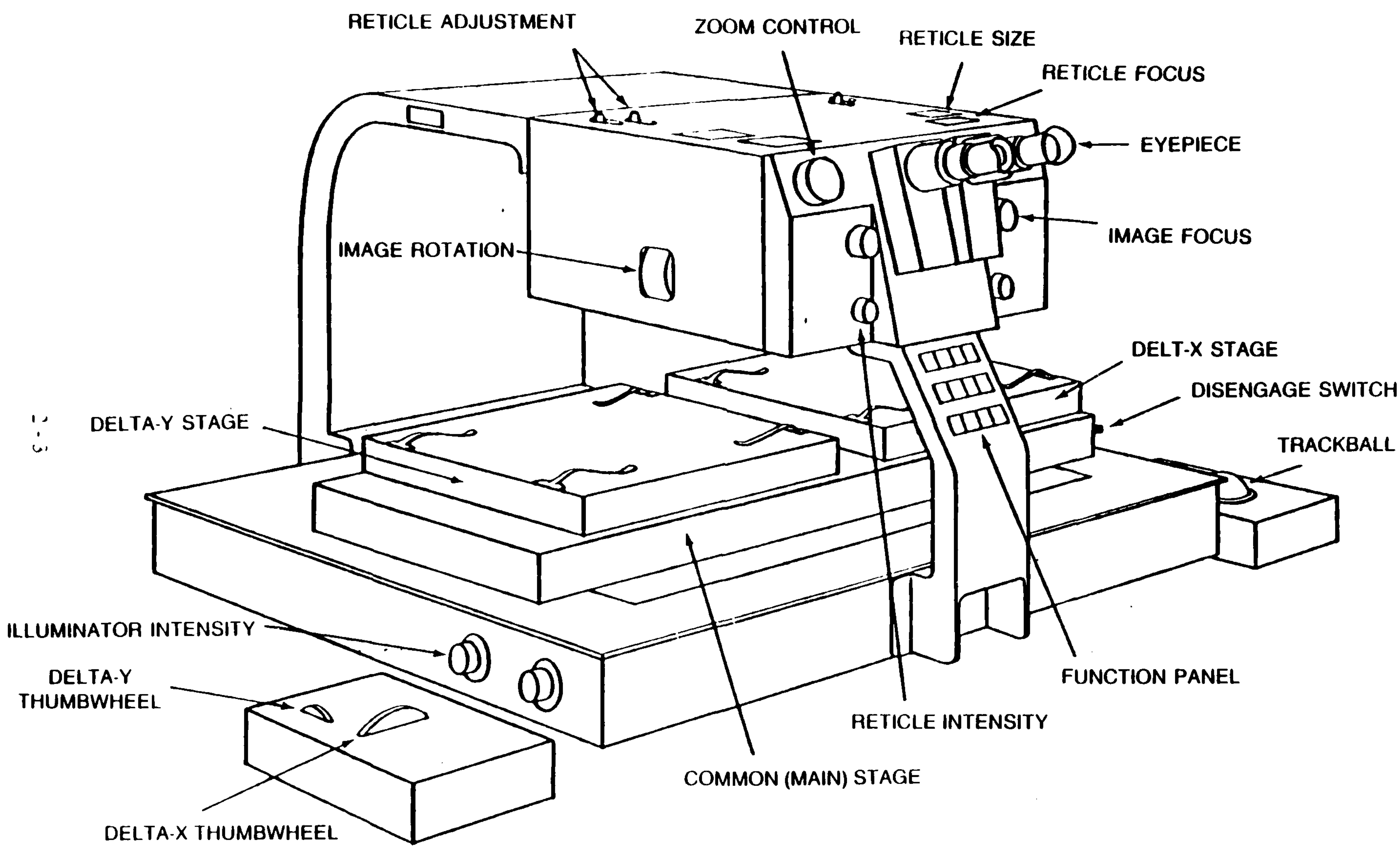


FIGURE 2. APPS-IV analytical stereoplotter.

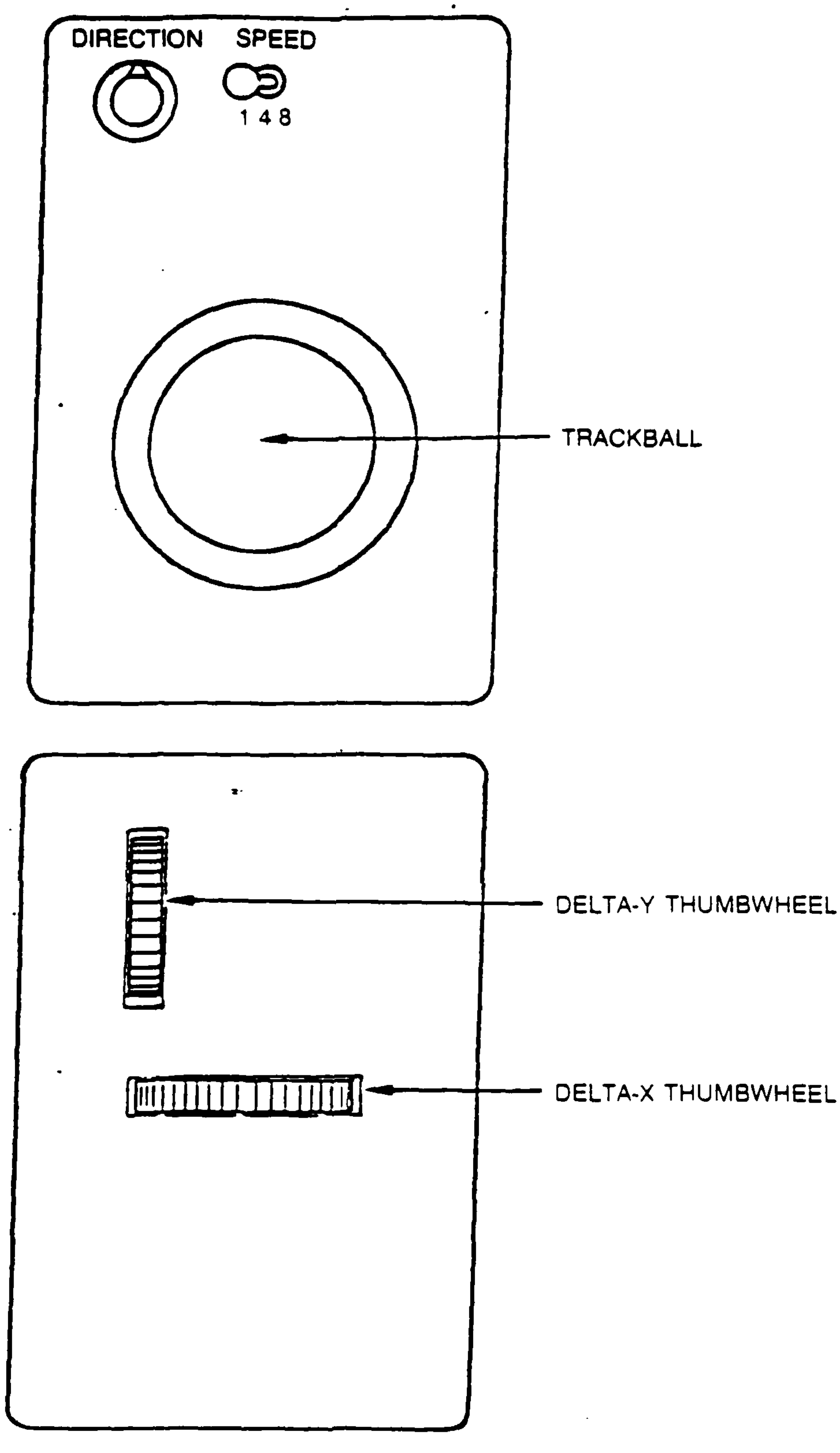


FIGURE 3. Thumbwheel and trackball.

Large movements of the stage are best done manually by pressing the stage disengage button and moving the stage to the desired point. This method does not change the stereomodel setup. However, fine adjustments are difficult to make in this manner. Fine adjustments in the stage position are made using the trackball. This method is used when digitizing imagery. Initial stereomodel setup and later adjustment for parallax require independent stage movement. This is done using the X and Y thumbwheels. The stages may also be driven to a point, or along a transect, by choosing one of the special function modes on the function panel (fig. 4). This will enable the operator to digitize along a predetermined vector or to digitize at predetermined points along a line or an arc.

When in the digitizing mode, points must be established as line segment end points, or nodes. The foot pedal is pressed to "drop nodes." When a point or node is "dropped" (marked) using the foot pedal, the coordinates of the node are sent to the APPS-IV data files. This enables the operator to use his/her hands for moving the trackball and thumbwheels.

2.1.3 The Optical System

The standard optical system of the APPS-IV is a Model 3500 OEM Zoom Stereoscope with two reticle projectors. An optional set of one-half power parfocal demagnifiers is also available. The standard zoom ratio is from 6 to 36 diameters. At 36 diameters, the optics are capable of resolving in excess of 200 line pairs per millimeter at 50 percent contrast. This may be compared to the resolution of the following film emulsions that are in common use:

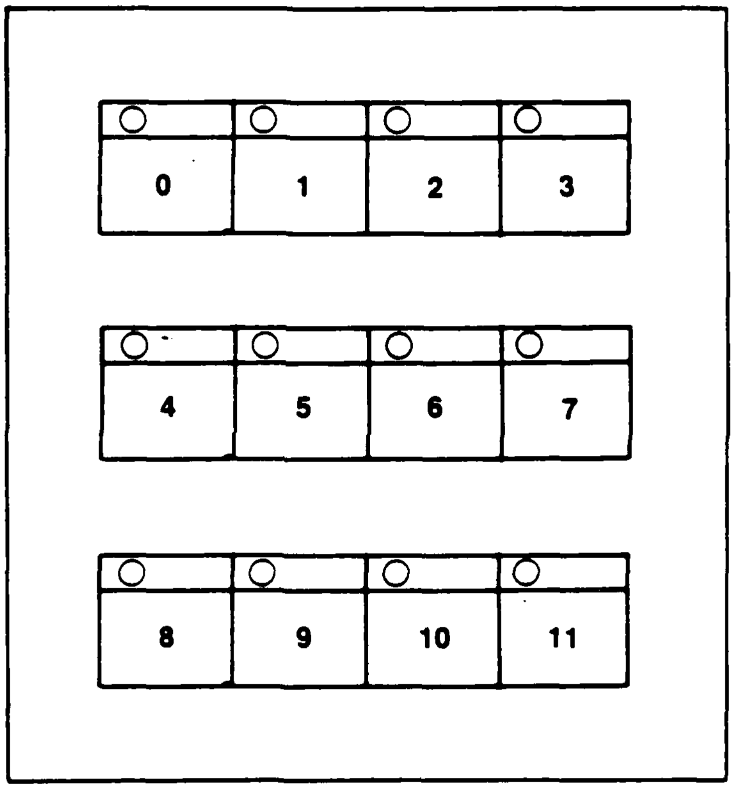
Resolving power of selected films in lines/mm

Film Name	target-to-object contrast 1000:1	1.6:1
Plus-X Aerographic	100	50
Tri-X Aerographic	80	20
High Definition Aerial	630	250
Aerial Color	200	100
Aerochrome Infrared	160	50

Controls are provided for independent image rotation and y-phoria correction. Additionally, there is an illuminated reticle projection system with 10, 25, 50, and 100 micron dot sizes. These are useful for mensuration, such as determining the size of rip-rap or tree crowns. The standard field of view is 180mm divided by the magnification. The field of view with normal optics ranges from 5 to 30mm. When the optional demagnifiers are used, the field of view is doubled and the zoom is halved.

2.1.4 Graphics Superposition

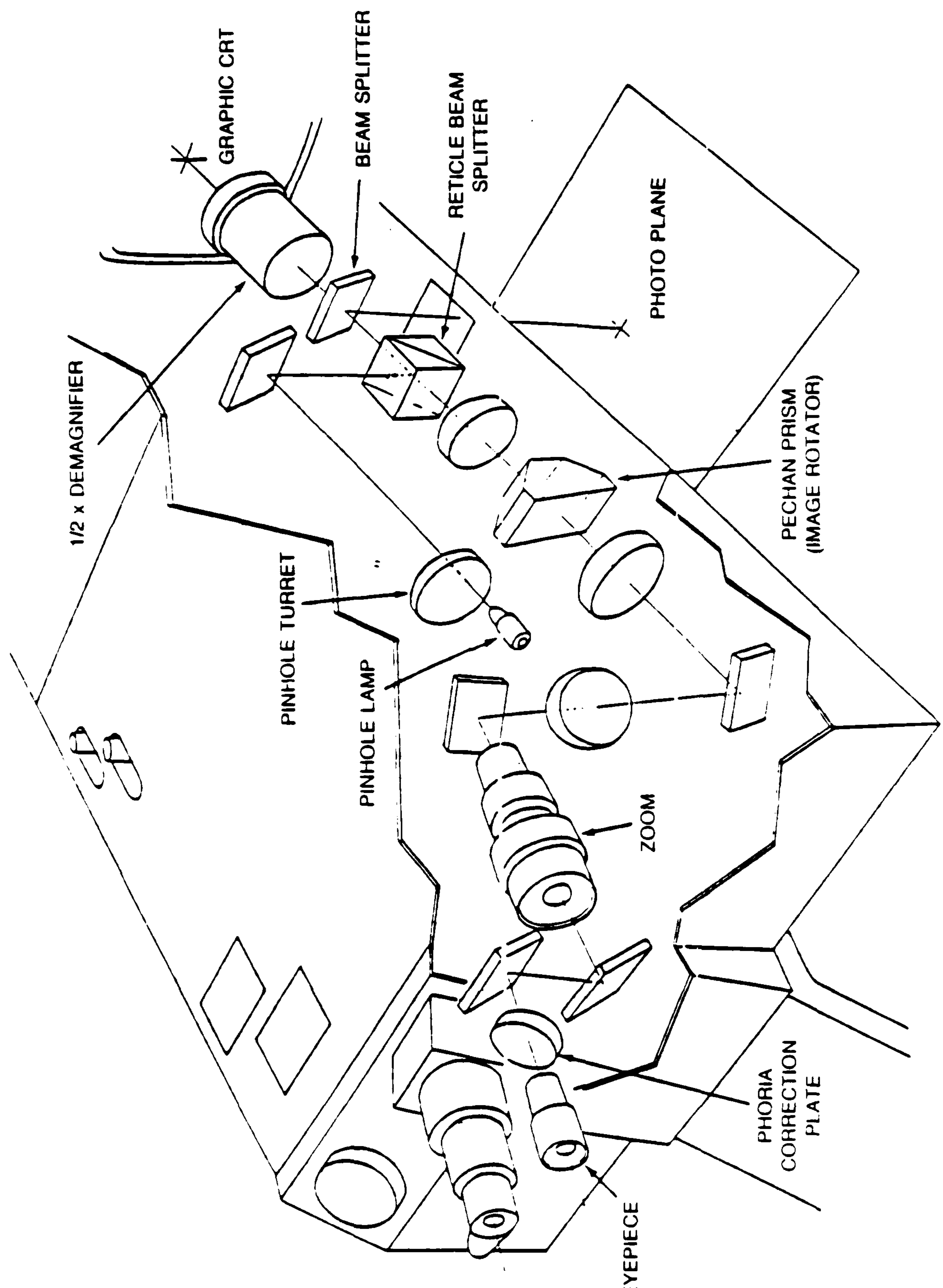
The most significant enhancement made to the APPS-IV instrument for the CAPIR system was the development of graphics superposition. Both single and dual optical path superposition are available. Graphics superposition provides the capability to view graphics from a stroke-refresh type of CRT optically superimposed onto a stereo model. Graphics superposition is accomplished through a second input channel at the objective end of the Model 3500 stereoscope. The digitized information is beam split into the optical path of the 3500 stereoscope (see figure 5) and optically displayed on top of the stereomodel.



Functions may be assigned by user.
On CAPIR:

0 - Stream mode	4 - Temp node	8 - Edit
1 - Point mode	5 - New node	9 - Wait
2 - Curve mode	6 - Old node	10 - Unassigned
3 - Unassigned	7 - Edge node	11 - On line

FIGURE 4. Function panel.


GRAPHIC CRT
BEAM SPLITTER
RETICLE BEAM SPLITTER
PHOTO PLANE
1/2 x DEMAGNIFIER
PECHAN PRISM (IMAGE ROTATOR)
PINHOLE TURRET
PINHOLE LAMP
ZOOM
PHORIA CORRECTION PLATE
EYEPIECE

2.1.5 X-Y Digitizing Table

The X-Y digitizing table is a standard backlit digitizing table that is connected to the APPS-IV and the host computer through a "black box" that emulates the signals of the APPS-IV. The system recognizes and uses the coordinates generated by the table in a manner similar to those generated by the APPS-IV.

2.2 The System Software

The system software is partially dependent on the host computer used. The Data General Eclipse, at ETL, used the Data General Advanced Operating System. Also available were system libraries containing International Mathematical and Statistics Library, array processors, and graphics packages for various output devices.

The software that is of greatest importance is the Automated Geographic Information System (AUTOGIS), which was designed by Autometric, Inc. This system is composed of the Analytical Mapping System (AMS) and the Map Overlay and Statistical System (MOSS). The AMS is used for setup and overlay generation, and the MOSS is used for data manipulation and analysis.

2.2.1 AMS Overview

AMS is designed to assist the analyst in four main areas:

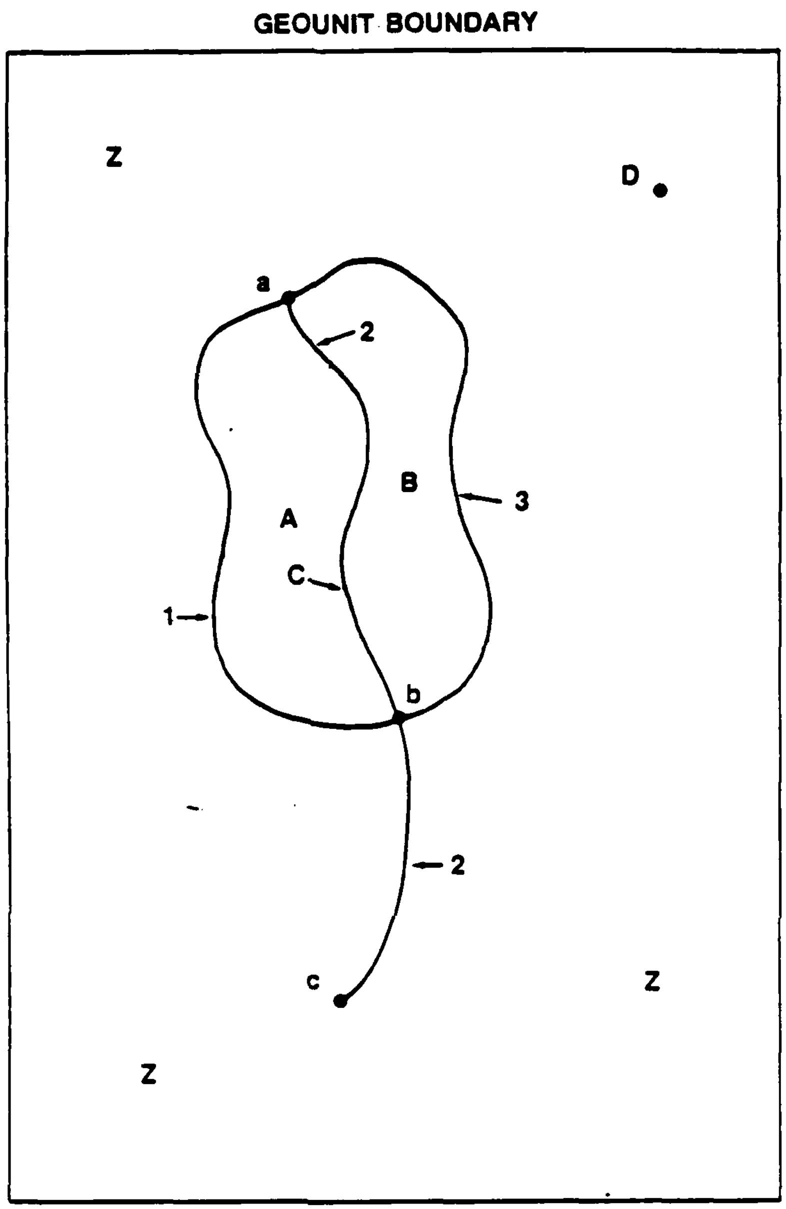
1. Analytical aerotriangulation
2. Digitization
3. Spatial verification
4. Data base management

These features enable the analyst to create a stereomodel, digitize data, verify the work, and store the completed document with little concern for the many photogrammetric considerations involved. The operator is led through the entire process by menus on the CRT. Analytical aerotriangulation requires the input of the following data:

1. Camera parameters
2. Ground control measurements
3. Image measurements
4. Frame estimates
5. Pass point estimates

The ground control may be derived from digital files or from a topographic map. The photo parameters are measured from the APPS-IV. The camera parameters are derived from camera calibration reports. A rigorous bundle adjustment program then solves the equations and outputs final frame, control point, and pass point positions, plus residuals and error propagation results. Points may be eliminated from the solution by the analyst to obtain a closer fit. The analyst also selects a check point to be used throughout the analysis to control stereomodel maintenance (loop close) and digitizing accuracy. The system can maintain up to 10 frames of photography in a stereomodel setup at one time.

The AMS digitization capabilities enable one to digitize by using three-dimensional (with the APPS-IV) or two-dimensional (with the X-Y digitizing table) source material. There are three feature types that may be digitized: points, lines, and polygons (fig. 6). To



NODES	ARCS	POLYGONS
a	1 with endpoints a, b	A formed by arcs 1 and 2
b	2 with endpoints c, a	B formed by arcs 2 and 3
c	3 with endpoints b, a	Z formed by arcs 1 and 3 and geounit boundary

Note: D is a POINT
Arcs have many other nodes which defines the shape of the arc.

FIGURE 6. AMS feature types.

form a point, the operator drops a node, using the foot pedal, essentially marking a point. The servo motors record the relative position of the point and download or "dump" the information to the data files. An arc is a line drawn between two nodes. After two nodes are designated, the system determines the best-fit arc between the nodes, usually a straight line. Arcs that enclose an area form polygons. All features must have left, right, and center attributes assigned to them.

1. Points have a center and one other attribute, with one of their attributes being null.
2. Arcs must have center, left, and right attributes.
3. Polygons have center, left, and right attributes (note that inside and outside attributes depend on the direction that the arc is digitized).

Attributes are assigned to the features during analysis. Features may be plotted later by attribute type when using MOSS.

Spatial verification is used after initial digitization to edit the overlay for minor errors. This is to ensure that the following parameters are met:

1. All polygons are enclosed.
2. All lines meet.
3. All features have attributes.
4. All attributes are defined.
5. There is no duplication.

This enables the operator to create a topologically valid digital data base that will be used for the MOSS analysis.

The geographic data base is formatted in a geounit that is nominally an individual USGS (US Geological Survey) quadrangle map sheet; however, the capability exists for the user to redefine the geounit. The minimum size is 2 seconds by 2 seconds, and the maximum size is one quadrant of the earth.

2.2.2 MOSS Analysis Overview

After digitization and verification under AMS, the data are sent to the MOSS data base for retrieval, analysis, and output. This transfer converts the arc-second format to metric and the latitude-longitude format to UTM, Lambert Conformal, Polyconic, or Albers. Data analysis is easier for the user, and more efficient for the system, to compute in these formats. The MOSS data base can contain 2000 maps (overlays), each having up to 16,000 polygons and 800 attributes. There are 70 commands in MOSS, which provide many capabilities for analysis and output. After the data are stored, the user can obtain a list of maps, subjects, legends, or polygons. It is also possible to select data from a map; save, merge, store, and retrieve maps; or determine the status of a map.

The 18 analysis functions in MOSS enable the operator to perform area, distance, frequency, and statistical functions. The capability to generate new maps from the combination of old data sets is very useful. For example, an analyst could combine old roads and new parking lots. This would create a map of paved areas. Creating the final hardcopy output may be done using one of the many graphic routines in MOSS and a suitable plotter. Many graphic functions are possible using MOSS commands; adding legends, shade, and print colors are but a few. In addition, it is possible to generate statistical reports of areas, lengths, and frequencies within a manuscript. The data may also be displayed in histogram form at the user's discretion.

3.0 Applications

A 1979 survey showed that each discipline within the Corps uses remote sensing for a variety of applications. The primary forms of imagery in use were black and white panchromatic, and color IR, low level aerial photography. Very few people were using LANDSAT or radar imagery to solve their problems.

If one is to determine accurately whether a project or projects may benefit from using APPS-IV or similar technology, the following questions should be answered:

1. Are all or part of the data in digital form already?
2. Will digital data be needed at some time?
3. Will the data be input to another digital data base, such as the Hydrologic Engineering Center's Spatial Data Management and Comprehensive Analysis System (HEC-SAM)?
4. Will there be many types of data (overlays) used?
5. Will it be better to digitize directly from imagery?
6. Will the data (or data base) be updated?
7. Will the same data be used for different types of analysis?
8. Will mensuration data (length, area volume) be needed?

The answers to questions one through three will help determine the need of digital data. Questions four through eight determine the specific need for APPS-IV CAPIR-type technology.

Corps projects are often long term. A major project may take several decades to go from planning to completion. In the future, information will be stored, manipulated, and analyzed in digital form. This will ensure a capability to access, update, transfer, and display the information. Because there is the need for digital data, combined with the need to analyze historical trends, the APPS-IV technology may be applied in numerous areas throughout the Corps of Engineers.

3.1 Examples of Prior and Potential Applications

Following are examples of projects that are of the type that could benefit from APPS-IV technology. The projects are separated by discipline.

3.1.1 Construction

Construction project managers are frequently concerned with accurately monitoring contractor performance. Some of the monitoring may be done with large-scale aerial photos to

1. Determine the volume of fill removed.
2. Monitor flood control measures taken by contractors.
3. Monitor soil erosion caused by construction activities.

Professionals analyzing large-scale aerial photography may quickly enter these parameters in a data base for reference and reporting.

3.1.2 Engineering Geology

Engineering geology requires a great deal of data derived from remotely sensed imagery, including orbital imagery. Determining general geological structure for project planning is one of the first uses of imagery in many projects. Regional structures may be mapped using LANDSAT, radar, SKYLAB, SPOT, and high altitude photographs. The

data may serve as the initialization of a digital data base for many projects. Other potential applications are as follows:

1. Detecting areas of actual or potential seeps.
2. Detecting areas of potential slope instability.
3. Locating potential construction material.
4. Detecting acid mine drainage.

3.1.3 Engineering Hydrology and Hydraulics

Flood planning requires land use information. Remote sensing is the best method available for quantifying major land use data. Although features such as basements and underground utilities are not visible, major factors such as developments, new industry, and impervious surfaces may be measured easily from imagery of appropriate scale.

Engineering Hydrology and Hydraulics personnel have also used aerial imagery for the following:

1. Determining erosion rates of streams.
2. Monitoring sediment transport along the coast.
3. Monitoring aquatic vegetation, its extent and location.
4. Preparing topographic maps.
5. Mapping the extent of floods.
6. Measuring snow pack.

3.1.4 Engineering River and Coastal

Many of the applications mentioned previously are also used in this function. Some unique to this area are determining wave action, monitoring coastal change, and designing coastal structures.

3.1.5 Operations

In addition to many of the previous applications, Operations personnel also prepare management plans for projects. These plans require detailed data on the amount and location of natural resources. Often the best method for obtaining the data is a combination of imagery analysis and field work. The management plan then becomes a data base for future work. Other application areas include the following:

1. Determining erosion rates of streams.
2. Monitoring salmon spawning to determine ecological impact of a project.
3. Monitoring kelp bed changes.

3.1.6 Planning

Planning personnel have found many uses for imagery in identifying and analyzing cultural resources, primarily archaeological sites. Other areas in which imagery has been used extensively are

1. Flood damage planning
   a. Prepare flood damage plans
   b. Determine flood plain build-up
   c. Map land use
   d. Compare pre- & post-storm
   e. Model the flood plain
   f. Prepare stream cross sections

2. Land use and environmental planning
    a. Environmental impact
    b. Historical change
    c. Mapping biota
    d. Acid mine maps
    e. Pollution monitoring
    f. Aquatic weed mapping
    g. Wetland mapping
    h. Natural resource inventory
    i. EIS and habitat evaluation
    j. Shoreline change
    k. Vessel counts

3.1.7 Real Estate

Real Estate personnel require imagery for mapping, appraisal, acquisition, and disposal of property. Most projects in the real estate field use imagery for mensuration or land use mapping.[4]

Frequently the imagery can be analyzed by cartographers and photogrammetrists to obtain the needed data.

3.1.8 Regulatory

Imagery is a very powerful tool that may be used to enforce the laws for which the Corps of Engineers is responsible. Historical photos can be compared with present conditions to establish the time and area of the violation. Other regulatory applications of imagery analysis are

1. Determining the extent of wetlands.
2. Detecting and monitoring pollution sources.
3. Providing data on water quality and water resources.
4. Maintaining an inventory (data base) of permits.

3.1.9 Applications Summary

In most functions, the Corps of Engineers is actively using remote sensing in one form or another. The types of data collected, the frequency of collection, and the future need for digital data ensure that systems such as the APPS-IV and CAPIR can be used for many, if not all of the following applications:

1. Monitoring soil bank coastal erosion.
2. Monitoring and mapping aquatic vegetation and wetlands.
3. Mapping land use.
4. Assessing flood planning and damage.
5. Monitoring construction, legal and illegal.
6. Mapping habitat and materials.
7. Detecting seeps.
8. Formulating management plans.

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[4] James D. Peroutky, *APPS-IV Remote Sensing Applications Guide*, Autometric, Inc., Falls Church, VA, Prepared for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0333, June 1983, AD-A134 977

4.0 Procedural Outline

This section will show in detail procedures used to create a topologically valid digital data base using an APPS-IV and CAPIR-type system.

4.1 Project Formulation-User Survey

You must keep in mind when creating a data format for a data base that the ability to enhance, intensify, and update a data base is essential for future use. You must also be able to obtain the necessary data from available sources.

The person or group that creates the data base must decide the size of the data base. The tradeoffs between greater usefulness and time (for computation and interpretation) must be carefully considered prior to designing the final data base.

Anyone creating a digital data base must create a detailed project plan. The first step is to determine all users, both known and potential. Then a survey should be conducted of these users to determine the following parameters:

1. What questions must they answer with the data base?
2. What do they feel their data needs will be, precision, accuracy, resolution?
3. What form of output will they need?
4. How often must the data be updated?
5. Do these users know of other potential users?

Step 5 is very important for it enables the data base creator to obtain leads to groups or persons that otherwise may have been missed.

Each response should be given a priority, which will assist in deciding the importance of the data needed to answer a certain query. Initially, all responses should be studied closely. This study will help determine the total range of future data needs. The user survey should culminate in series of lists for each potentially valid factor (drainage, land use, land cover, etc.), which will serve to define the data sources needed. These lists should be in a form that enables one to interrelate each item and assign priorities to users and products.

4.1.1 Project Preparation

After you have selected the optimal data set for the data base, you must obtain the data. The three sources of data - imagery, maps, and collateral data (including other digital data) - must be integrated into the same data base, and all must meet some minimum criteria for accuracy. In general, sources must meet the following criteria:

1. Photography
   a. Ground control points must be visible.
   b. Fiducial marks must be precisely located and easy to measure.
   c. Camera calibration reports must be available.
   d. The imagery should be of mapping quality.
   e. The tones and quality of the image must enable you to detect, identify, and measure the features of interest.

2. Maps
   a. They must be on stable dimension material.
   b. They must be of an accurate scale.
   c. They should be recent and should accurately portray potential ground control points.
   d. If they are photocopies or diazo copies their dimensions and scales must be accurately checked.

3. Collateral sources
   a. If general in nature, they should be of high quality.
   b. If specific, they should have precise locations of feature occurrence (e.g., coordinate of tide gauge).

When the data are obtained, be sure to keep an up-to-date catalog of all pertinent parameters, such as date, source, type, scale, location, etc.

4.2 Project Setup

The actual use of the APPS-IV is covered in this section. Many of the steps are also outlined in Autometric's "APPS-IV Operation Manual."[5] In many instances, the actual setup will involve the use of both the X-Y digitizing table and the APPS-IV.

4.2.1 Power On Restart

Inside the electronics cabinet are two toggle switches, an indicator light and a reset button (figure 7). To turn the power on, switch both switches on. The indicator light will glow when the power is on. If the power is already on and you wish to restart the system, push the reset button.

4.2.2 Lights

Light intensity control knobs are located on the left side of the base of the instrument (figure 2). The heat generated by the lights causes the APPS-IV components to expand; therefore, you should let the machine "warm up" for about 20 minutes. This procedure will enable the components to reach their operating temperatures and cease expansion.

4.2.3 Stage Positioning

There are three stages that the photos lie upon (figure 2). Movement of the main stage moves both left and right photos; movement of either the delta x or delta y stage (photo stages) are controlled by the thumbwheels.

CAUTION - All the stage motions are servo driven with slippable friction drives; thus, they will not be damaged if driven up against a stop. However, when driven up against a stop, the motors continue to run. If the stage is left against a stop with motors running the drive will eventually fail.

A disengage switch is located on the right side of the photocarriage and enables "high speed slew" of the main stage. While keeping the button depressed, gently move the main stage by hand to the desired location (when the button is released, the fine motion drive is automatically engaged). The fastest allowable rate of movement is about 25cm per second. This mode of movement is best used for general scanning or for measuring fiducial marks.

The trackball controls the fine motion drive. Trackball movements are transformed into pulses sent to the stage drive's servo system, moving the stage. The speed select switch on the trackball box has three speed ranges to allow three rates of movement. Normally, 1 degree of trackball rotation causes 1 micrometer of stage movement. This is the most precise mode of movement and is normally used for measurement. The other two speeds are ratios of 1:4 and 1:8 degrees of rotation: micrometers of movement, respectively.

The delta x or delta y stage (photo stages) controls are the thumbwheels. The right stage (delta x) moves only in the x direction, and the left stage (delta y), only in the y direction. These are used in initial model setup and correction for parallax while digitizing.

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[5] Autometric Inc. *APPS-IV Operation Manual*. Falls Church, VA 22041, 1983

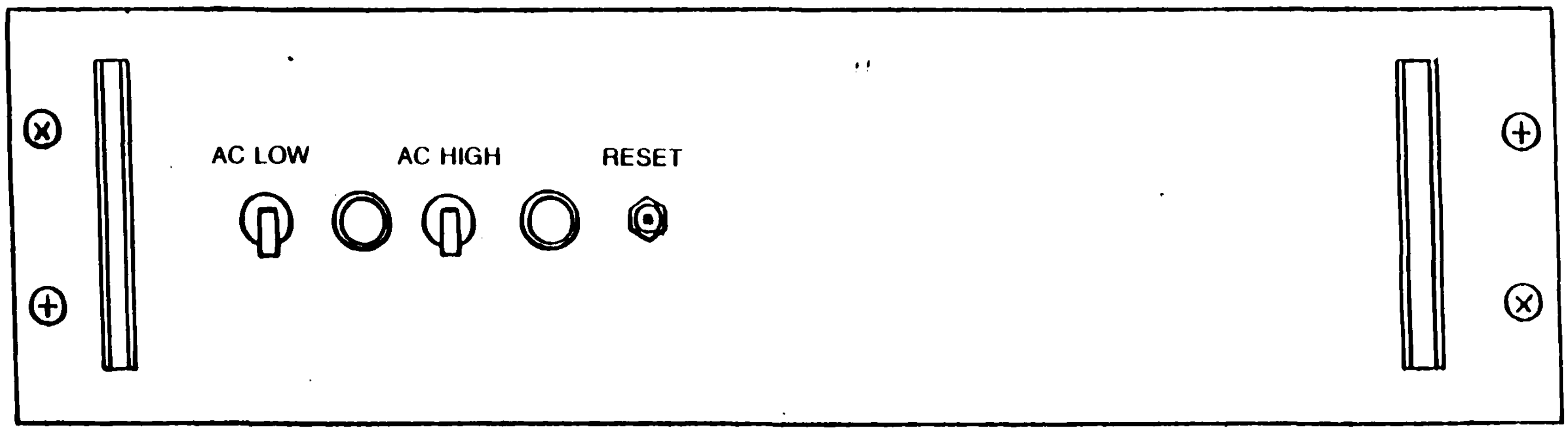


FIGURE 7. Toggle switch diagram.

4.2.4 Adjusting The Eyepieces

With both photo stages lit, look through the eyepieces (figure 8) and slowly rotate the eyepieces assemblies until you see a round image (which may not be in focus). The measurement between lens centers is the interpupillary distance (IPD) and should be remembered for quicker future setup.

4.2.5 Mounting The Photos

Center each photo stage and place the photographs upon the proper stages, such that the flight line goes from left to right. Be sure to position the photos such that all the fiducials may be read. If film material is used it is advisable to put a clear glass plate on the film to prevent curling. If glass diapositives are used place them emulsion side down to prevent scratching.

4.2.6 Focusing The Eyepieces

The imagery must be focused for each eye individually, which should be done with both eyes open. If you find it difficult to view the simultaneous images, turn down the light level on the stage not being focused. Working with either image, turn the zoom (magnification) to the minimum and focus with the eyepiece focusing ring. This ring should only be used to make adjustments at minimum zoom. Turn the zoom clockwise to maximum magnification and focus using the image focus control knob. The image should now be in focus throughout the zoom range. Repeat this procedure for the other eyepiece. The images will appear as two separate images (unless they happen to be in stereo alignment). After both images are in focus, adjust the magnification and illumination to the levels at which you will analyze the imagery and put the photos in rough stereo alignment. To align the photos, unclip one and manually move the photo (not the stage), while looking through the eyepiece, until the images fuse and a stereo match is obtained. Do not obscure the fiducial marks.

4.2.7 Focusing The Reticles

The reticles are used as measuring marks and a point of reference. They appear on each image as a white dot of light. Prior to focusing the reticles, the following setup should be performed:

1. Select reticle size by rotating the reticle size wheel (figure 2) until it clicks (locked position). Four positions with sizes of 10, 25, 50, and 100 micrometers are available.
2. Rotate the reticle intensity control knob (figure 2) clockwise to the desired brightness. This should enable you to see the reticles.
3. If you cannot see the reticle,
   a. Check to see that the reticle bulb is not burned out, if so replace.
   b. Turn the reticle position controls until the reticle is in the field of view (see below).

To focus the reticles, turn the reticle focus knob until a bright dot (without halo or glare) is seen. After both reticles are in focus, they must be brought into stereo. There are two sets of knobs, on the top and back of the optics housing, that are used to move the reticles. The outer knobs move the reticles in the Y (vertical) direction, and the inner knobs move them in the X direction. Center each reticle within your field of view. When viewed simultaneously, they should merge into a single dot.

> Caution. Any changes in optics rotation, magnification, or reticle size will now alter reticle focus and produce inconsistencies during mensuration.

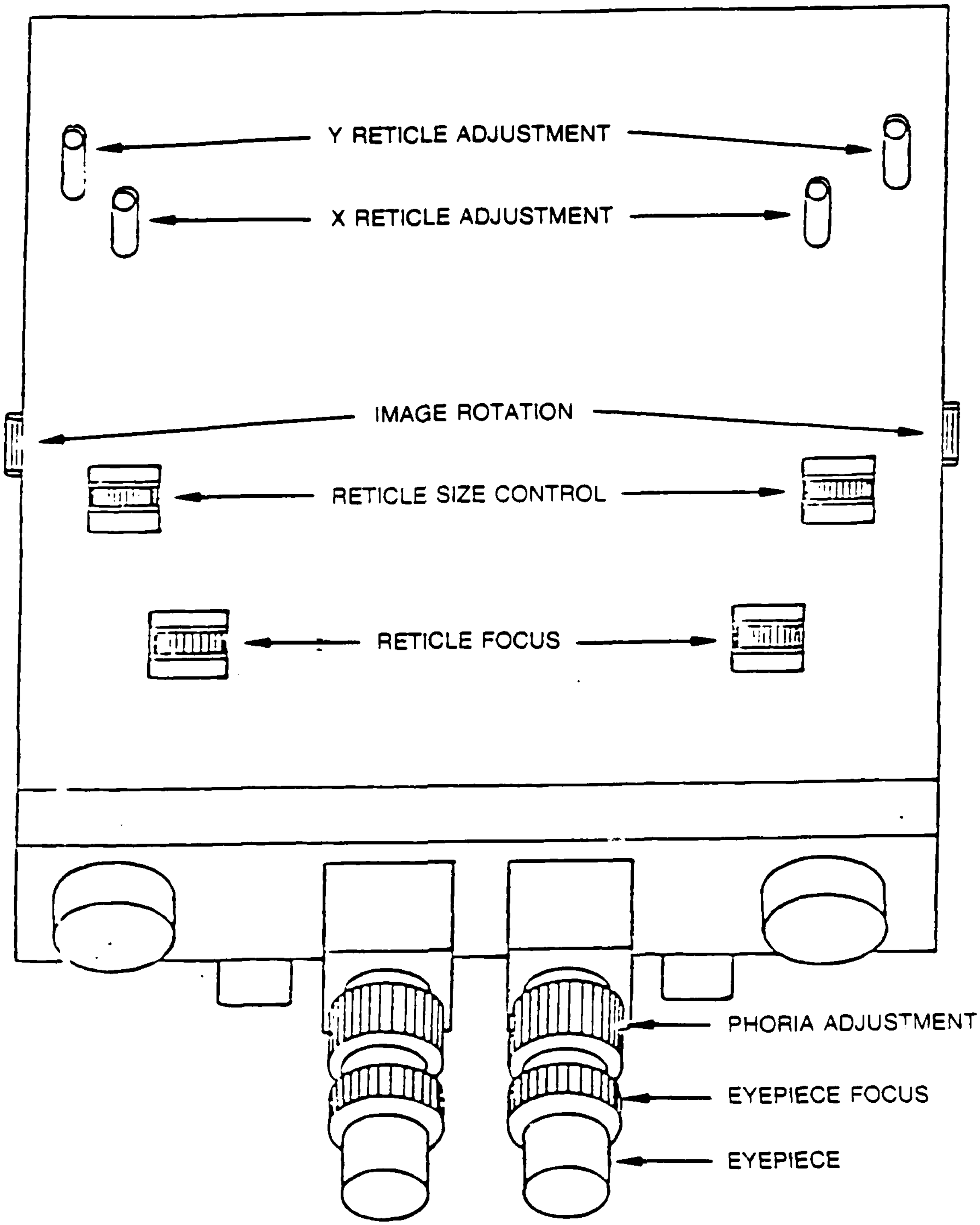


FIGURE 8. Optical system, overhead view.

4.2.8 Manually Engaging Stereo

With the lights turned up, bring the area of photo overlap (stereo area) into view by manually moving the photo carriage (press disengage button). Using the delta X and delta Y thumbwheels, bring the photos into stereo alignment.

> Note. Since the stereo maintenance function is not yet engaged you may only see the central portion of the field of view.

4.3 Aerotriangulation

Aerotriangulation must be done very carefully, because any mistakes made during the aerotriangulation procedure will carry through the entire digitization and jeopardize the projects validity. Many factors must be accounted for to achieve a topologically valid model (stereo pair), many of which may require many small adjustments and each adjustment of a factor may have a synergistic effect with another factor. At times, the process may seem frustrating.

The essential steps in aerotriangulation are as follows:

1. Select ground control points.
2. Mark the control points.
3. Determine the latitude, longitude and elevation of the ground control points on a map sheet, using either the X-Y digitizing table or the survey data as ground control.
4. Create a project and a project area (geounit).
5. Enter camera calibrations into data base.
6. Enter ground control points into data base.
7. Select pass points.
8. Measure photo control and pass points on the APPS-IV.
9. Perform triangulation solution.
10. Enter results into frame data base.

4.3.1 Selecting Ground Control Points

The ground control points must be sharp and you must be able to precisely locate them on both images of a stereo pair set. If the same area on the ground is covered by more than one set of imagery, it is best to select control points visible on all the sets of imagery. Ground control points are of two types:

1. Horizontal control - these are points where you can accurately locate the latitude and longitude, however the vertical elevation is not as accurate. There should be at least one point per model.

2. Vertical control - The elevation is accurately known, but the horizontal parameters are not as accurately known. There should be at least one point per model.

NOTE. The same point may be used for both horizontal and vertical control. However, there is an absolute minimum of three points, with at least one of each type, per stereo model.

You should select a sufficient number of ground control points such that some may be discarded later. This will ease the triangulation solution.

When selecting points, you should also examine the imagery closely for additional features that may warrant digitizing. This is a chance for an initial introduction to the imagery.

4.3.2 Delineate the Ground Control Points on the Imagery

The ground control points should be delineated on the imagery accurately; a pin prick in the transparency is an excellent method. Also, the points must be accurately marked on the map, unless ground survey data is used to establish their position.

4.3.3 Map Measurement of Ground Control Points

Ground control points must be measured on the map sheet, using X-Y digitizing table, or some method to determine precise latitude and longitude of the horizontal control points. The greater the accuracy of the control points, the greater the potential accuracy of the product.

If the location of the control points is in some coordinate system other than latitude and longitude they must be changed to latitude-longitude prior to entering them in the data base. There is a utility function that may be able to transform the coordinates to latitude-longitude points prior to entering them in the aerotriangulation data base.

4.3.4 Creating a Project

The first step in interacting with the computer is creation of a project and project area, or geounit. After entering AMS on the computer, select the option of PHOTOGRAMMETRY, then FRAME DATABASE; then enter your project name, etc., and exit to the main menu.

Next select DATABASE, then PROJECT CREATION. In this step you name your project and define the project boundaries in latitude and longitude. If your project area is large, there is an option to subdividing the entire project area into smaller units.

4.3.5 Camera Data Base

You should now enter the camera calibrations into the camera data base (PHOTOGRAMMETRY, then CAMERA DATABASE). The camera calibration report for the camera and lens used for the imagery that you will digitize should contain all of the information needed:

1. Make of camera and lens.
2. Serial number of camera, magazine and lens.
3. Focal length of lens.
4. The indicated principal point.
5. The displacement of the fiducial marks from the principal point (X and Y displacement).

Prior to entering the data, you must give the camera a unique name, such as RMK1, that does not duplicate any camera name already in the camera data base.

In addition to the above information you will need initial estimates of the instantaneous spatial orientation of the image, i.e., the direction of flight (kappa). Kappa is the rotation around the Z axis; thus, it is displacement of the flight line from true north. On some versions of the software the direction of flight, with 0 degrees being north, must be subtracted from 450. Thus, due south, 180 degrees, becomes 270 degrees.

After entering the data, edit the camera data base to ensure correctness. Minor mistakes, such as an incorrect computation of latitude, may cause the entire model to not triangulate properly.

4.3.6 Ground Control Point Data Base

You should now enter the ground control data into the aerotriangulation data base (PHOTOGRAMMETRY, AEROTRIANGULATION, ENTER TRIANGULATION INFORMATION). Each point must be assigned a unique control number and should have an elevation associated with it. All points should be in the form of DD,MM,SS.SSS (degrees, minutes, seconds). Each point must be assigned a sigma value accuracy for both horizontal and vertical control. The smaller the sigma, the more tightly constrained the model will be; thus, the more accurate your measurements must be.

Again, edit the points entered prior to continuing.

4.3.7 Selecting Pass Points

Pass points are photoidentifiable points that are used to fill in between ground control points. There should be three or more pass points common to each stereo pair. These points must be precisely located on the imagery, but only generally referenced on the ground. A good practice is to create a small sketch of each pass point and indicate precisely where it occurs, such as the center of an intersection or a certain telephone pole.

4.3.8 Photo Control And Pass Points

Referring to section 4.2.8, set up the APPS, with the photos in stereo and the smallest reticle size you are comfortable with. You must then enter the menu choice of setup model: measure fiducials (under PHOTOGRAMMETRY, AEROTRIANGULATION, ENTER TRIANGULATION INFORMATION). You will then be asked to enter the roll, frame, and camera numbers and to measure the fiducials for each frame. After setting up the model, go to the image measurement choice.

The process is self explanatory; however, you should note that when the model is first set up, *the first point entered after you measure the fiducials will be used as the checkpoint* during digitization. Therefore, choose the first point carefully and make sure it is easy to recognize and locate. After you set up the model, you may be asked to enter the checkpoint prior to entering any image points. When this message occurs just after model setup you may disregard it.

Next enter the image ID and place the reticle (floating dot) on the ground at the desired control point or photo pass point. Use the X and Y thumbwheels to place the dot at ground level, use the trackball for minor movements, and use the stage disengage button to move over large areas.

4.3.9 Triangulation Solution

In theory, you have entered sufficient ground control points and are ready to perform triangulation. The setup for triangulation was the measuring and entering of the ground control points, the photo pass points, and the checkpoint for each model. Carefully edit the triangulation for any mistakes in entering data and ensure that all ground control points have matching image points.

The actual triangulation is performed by selecting the "triangulation solution" (PHOTOGRAMMETRY, AEROTRIANGULATION, ENTER TRIANGULATION SOLUTION) choice on the aerotriangulation menu. The screen prompts will then be answered and the program will compute a triangulation solution. If the final solution yields X and Y photo residuals all less than 20 (microns), the answer is acceptable.

Because of the large number of variables there are many possible parameters that may prohibit convergence of the solution, such as the following:

1. Ground point coordinates incorrect. Solution—check all coordinates.
2. Sigma values are too restrictive. Solution—ease the sigma values.
3. Kappa incorrect. Solution—re-estimate, or try values at every 90 degrees.
4. Points mismeasured on image. Solution—if there are a sufficient number of points per model (six or more), edit the point by changing its status to 0 from 1.

4.3.10 Entering Results into Frame Data Base

This step is taken after a successful triangulation solution has been achieved. Select the choice from the menu (PHOTOGRAMMETRY, AEROTRIANGULATION, ENTER TRIANGULATION RESULTS INTO DATA BASE). The present software then immediately enters the solution into the frame data base and returns you to the aerotriangulation menu. To ensure that the solution is in the frame data base, return to the photogrammetry menu and view the frame data base.

4.4 Digitization in Stereo Loop-Close

Digitization is the process of delineating features on the imagery and simultaneously encoding the information in digital format. You delineate, the APPS-IV digitizes. The process, once started, is simply one of either dropping nodes or digitizing in stream mode, unless a special function has been chosen. As explained previously, nodes are points that connect arcs, which are lines, to form polygons.

4.4.1 Initial Entry into Loop-Close

After the aerotriangulation solution has been entered into the data base, you can enter the digitization process. First, set up classification schemes and themes, then select the digitization option. When following the menu, it is important to enter under new job the first time.

You must set up the photos and measure the fiducial marks and a checkpoint if the photos have been moved since the fiducials were last measured or if the machine had been turned off. For the checkpoint, select the point that you had first entered into the data base for an image control point. The APPS-IV then downloads the camera parameters and engages loop-close.

4.4.2 Superpositioning

After loop-close is engaged, the option to engage stereo superpositioning (if the machine is so equipped) is available.

Following the menu choices, select your option. If you select superpositioning you must then select a ground point for the superpositioning reference system. A crosshair will appear in one quadrant of the optics; you must then move the object, using the trackball, under the crosshair. This process is repeated for each quadrant of each field of view. Superpositioning should now engage, and a green dot will appear on each active channel at the reticle.

4.4.3 Actual Data Collection

You are now ready for actual digitization. Following the menu, define the left, center, and right attributes for the arc you will digitize. To drop a node, press the foot pedal. To digitize a line, drop nodes along the line you wish to digitize.

There are two normal modes of data collection—stream and point. These are selected by choosing the correct selection on the function panel (figure 4). Stream mode digitizes a continuous stream of points as the table is moved. This mode is very demanding on the computer. Point mode only downloads the points where arcs are to be connected. Point mode requires less host computer time and is used most often. The APPS-IV is automatically placed in point mode after loop-close is engaged.

4.4.4 Special Function Modes

There are two special functions that are software dependent and are usable when in loop-close. Vector mode is used to automatically drive the APPS-IV to a ground point. Profile mode is used to collect data along predetermined lines or arcs at selected intervals.

In vector mode the floating dot (reticle) can be driven along any general line in the ground space, that is either vertical, horizontal or any combination of either. The general equation used by vector mode is

$$X = A + B*Z$$
$$Y = C + D*Z$$

where A, B, C, and D are software-set constants, and X, Y, and Z are the ground point coordinates.

Once the APPS-IV has arrived at the initial point determined by the above equation (the current value of Z is used for this), the operator may use the delta-x thumbwheel to move along the line. In the case of the simple drive mode, where the constants B and D are set to zero, this action results in a simple vertical movement.

Note that any slew motion or trackball movement will result in the APPS-IV moving back to the point determined by the equation. The software will handle the disengaging of vector mode.

In the profile mode the APPS-IV is given the characteristics of a profile and is then driven along the profile by use of the trackball. The profile mode is engaged by using the vector mode. You are then prompted by the software to begin profile data collection. To start the profile, the trackball is used as a throttle. By rotating the trackball toward you or away from you a small amount, you should see the floating dot begin to move down the profile.

The general equation of the profile that can be used by the APPS-IV is

$$X_{i+1} - Y_i = a_{11} + a_{12}*X_i + a_{13}*Y_i$$
$$Y_{i+1} - Y_i = a_{21} + a_{22}*X_i + a_{23}*Y_i$$

where

the coefficients (a_{11} ...a_{23}) are constants used to describe the profile line or arc

X_i, Y_i denotes the coordinates of a point in the profile

X_{i+1}, Y_{i+1} denotes the next point in the profile

Note that the above equation is sufficient to model gentle arcs or curves, such as those commonly associated with road or railway design.

The profile interval at which points are taken is defined as the straight line distance between consecutive points in the profile within some tolerance. This distance is a function of the coefficients in the preceding equation.

Once the dot begins to move down the profile, data collection will begin. The speed at which the dot moves along the profile can be governed by the trackball; by rotating the trackball, the motion will be accelerated. By reversing the direction of rotation of the trackball, the operator can slow or stop the motion of the dot, or reverse its direction of travel.

The delta-x thumbwheel is used to keep the dot on the ground and thus insure a correct reading when a profile point is actually transmitted to the host computer. You can perceive a subtle stop in motion of the floating dot when a profile point is taken by the APPS-IV firmware.

You can recollect (edit) data along the profile by rotating the trackball in the reverse direction until the dot begins to travel backwards along the profile. Each point now encountered will be recollected by the firmware, and the software is responsible for acknowledging the new value for the point. You are free to change direction and speed at will.

If the wait light is turned on and the reticle extinguished by the APPS-IV, you must wait while the host computer catches up with the data being sent by the APPS-IV.

The firmware will keep track internally of the final point of the profile, and the end of collection is signified by a stopping of forward motion at the end point. As in vector mode, the host software will control exiting from this mode.

4.5 Verification

Once you have successfully digitized the information that you want in your data set, it is time to verify the data set. Verification is the process of editing the data set for errors. This fully automated procedure ensures that you will have a topologically valid data set prior to output to MOSS. To verify the data set, check for the following conditions:

1. All polygons must be enclosed.
2. Illegal attributes.
3. Missing attributes.
4. Missing nodes.
5. Illegal nodes (less than 3 arcs).
6. Missing arcs.
7. Duplicate arcs.
8. Kinks within an arc.
9. Spikes (arc overshoots a node).
10. Gaps.

The verification process is carried out in several steps. In the first step, delete previously verified features that contain a segment that has been deleted or an attribute that has changed since the last attempt at verification. The file of deleted segments contains a list of these segments.

In the second step, check the nodes for various conditions. Basically, any normal node (not an edge or temporary node) must have at least three line segments associated with it unless certain conditions prevail. If only one segment enters, then this segment must be one that enters a polygon, and it must have two side attributes and a center attribute. An example of such a segment would be a stream entering, but not passing through, a polygon.

In the case of two segments entering a node, one of two conditions can prevail. The segments can both be a part of a simple loop, in which case both segment identifiers will be identical. The second case is a loop that, for some reason, is broken by a temporary node. In this case, both segments entering the node must terminate on temporary nodes. Any node having two or fewer entries that does not satisfy one of the above conditions is in error, and an appropriate error message will be displayed on the console.

Because certain special conditions pertain to those features that contain edge nodes, they are verified first. The edge nodes are first sorted (starting at the northwest corner of the geounit and proceeding in a clockwise manner). Next, the formation of the features is begun. Each edge node is used in turn, and the feature that is on the right as one leaves the edge of the geounit is verified. If there is a left attribute, it will be used when a later feature closes on that edge node. One type of error, therefore, is the case of a left attribute that never gets used. If this error occurs, an appropriate error message will be displayed on the operator's console, and the edge node involved can be highlighted on the graphics display to aid in correcting the error.

The other errors that can occur, both in the edge node feature verification and in the normal node feature verification, take the form of errors that occur at nodes, which prevent the program from deciding which segment it should use to leave the node. In all of these cases, an error message is displayed to guide the user to the problem. When errors in verification occur, an error message is displayed and program control returns to the digitizing monitor.

5.0 MOSS

After you verify the data, you are ready to transport the data to MOSS. The EXPORT command in AMS is used for the transfer of data to MOSS. During the transfer, the coordinate data are transformed from latitude-longitude to UTM, Lambert Conformal, Polyconic, or Albers coordinates for the actual data analysis. This process increases the efficiency of computational tasks by converting coordinate data to metric units.

MOSS is a completely interactive system that you can run in batch mode for the storage, retrieval, analysis, and display of digital map data. Projects as small as one map sheet or as large as hundreds of map sheets may be handled with equal ease. To date, MOSS has been used for Environmental Impact Statement work, habitat analysis, wildlife refuge management, terrain analysis, geologic interpretation, strip mine leasing alternatives analysis, reservoir studies, wetlands change detection, and general report generation and mensuration.

Using MOSS you may store access point data, line data, polygon data, point elevation data, raster (grid cell) data, Digital Terrain Models (DTM), and binary bit maps in the same session. MOSS also has facilities for changing from one data type to another, such as polygon to raster. You may mix raster data, DTM data, and vector data on the same display. There are a number of methods for retrieving data from the data base. Attribute selection, size selection, and proximity selection are all supported for vector data, and boolean or arithmetic selection is available for raster filtering. There are 65 different analysis and display functions that can be applied to the data once they have been retrieved from the data base.

The rest of the chapter has been taken from the MOSS USER'S MANUAL, v82.11, U.S. Fish and Wildlife Service.[6]

[6] U.S. Fish and Wildlife Service, *MOSS User's Manual*, Data Acquisition and Computer Services Unit, Western Energy and Land Use Team, Fort Collins, Colorado, v82.11

5.1 MOSS Data Organization

Three files store data in MOSS (figure 9):

1. Master map file - This is a central library in which the original digitized geographic data is stored. Usually there is a separate file for each study area so that data of different quality or resolution cannot be readily mixed.
2. Cell map file - This is a work file which is a working space for storing active data which is in a cell or regular grid format. Each cell is given an identifying code based upon its characteristics. (figure 10).
3. Polygon work file - A file for data stored as a series of X,Y coordinates (figure 11).

Master files are not alterable by the user; work files are used for adding and deleting maps. Although some MOSS commands use cellular data, the majority of analysis and display commands use polygon data.

Generally, only a portion of the data in the master map file or work file is ever needed to solve any given problem. Consequently, you must activate the data that will be needed for display and analysis. (A map cannot be analyzed or displayed until it has been activated.) Activating data is very similar to retrieving documents from the shelves of a library for review and analysis. You may activate data from both the master map file and work file or synthesize data from existing maps.

Reference to the active data is maintained in an active map data table. Each entry in the table is given a unique identifying number. This number identifies the active map that you wish to analyze or display.

5.1.1 MOSS Directory

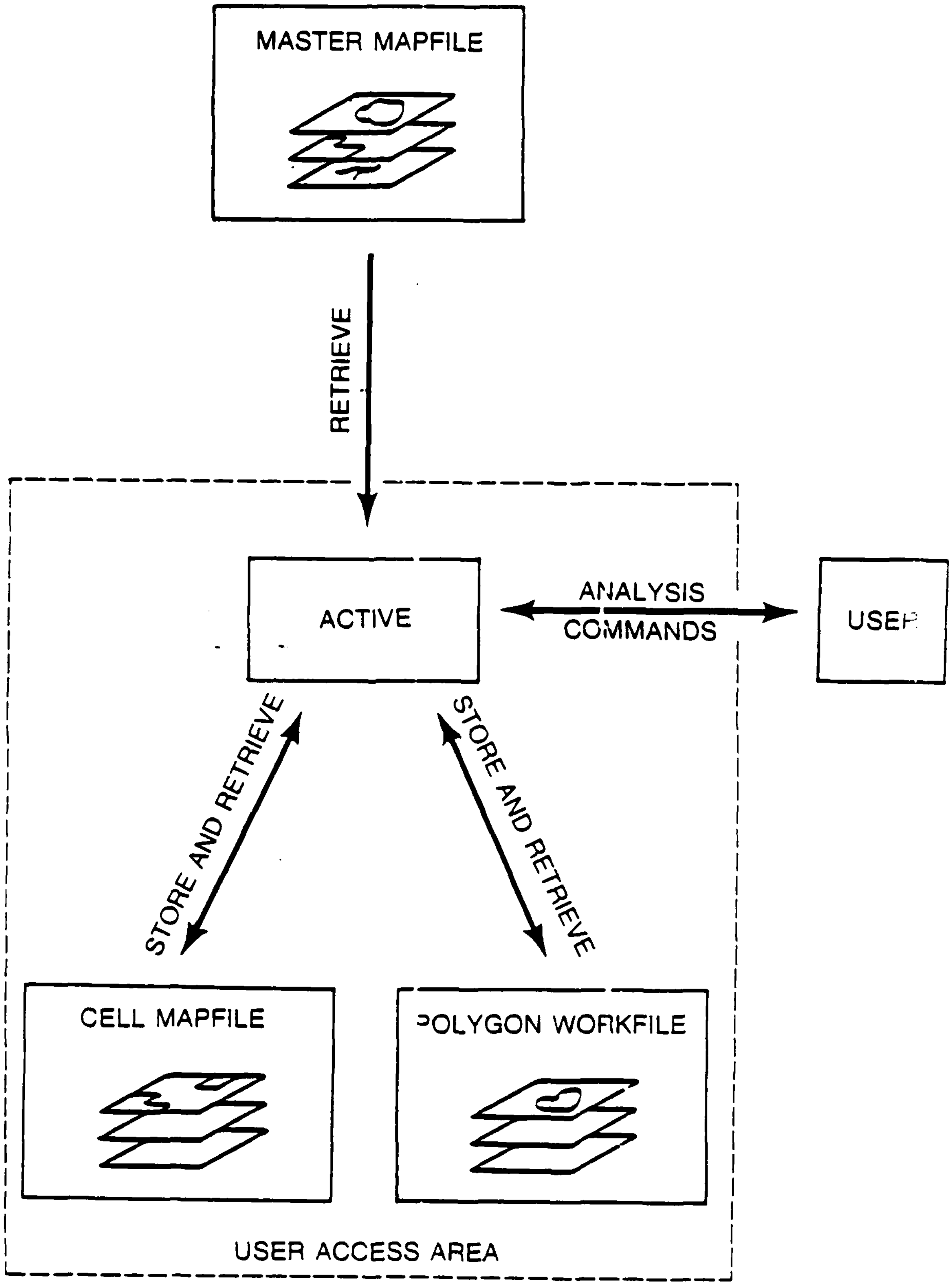
Associated with the master map file is a hierarchical directory that enables users to browse, archive, de-archive and retrieve the map data stored in MOSS. Each map in a master map file has a map name, a subject and an item. A name (MDRSMIZGL) identifies each map. Each map is subdivided according to its subject: WINTER RANGE, MIGRATION ROUTE, etc. Each of these subjects may be further subdivided into items or particular segments. The hierarchy associated with any map is a function of the inherent complexity of the map and the specifications provided by the users at the time the data were digitized.

The hierarchical design of the master map file enables all or a specific portion of a map to be activated or retrieved. For example, at the map level, one specific subject or all subjects may be retrieved. This capability greatly increases the efficiency of map data processing and enables one to avoid unwanted detail or data.

Each master file map also has an associated header containing information on the source, vintage, projection, description, and other characteristics of the digitized map. In general, the information in the map header is useful for determining the suitability of a map for a particular analysis.

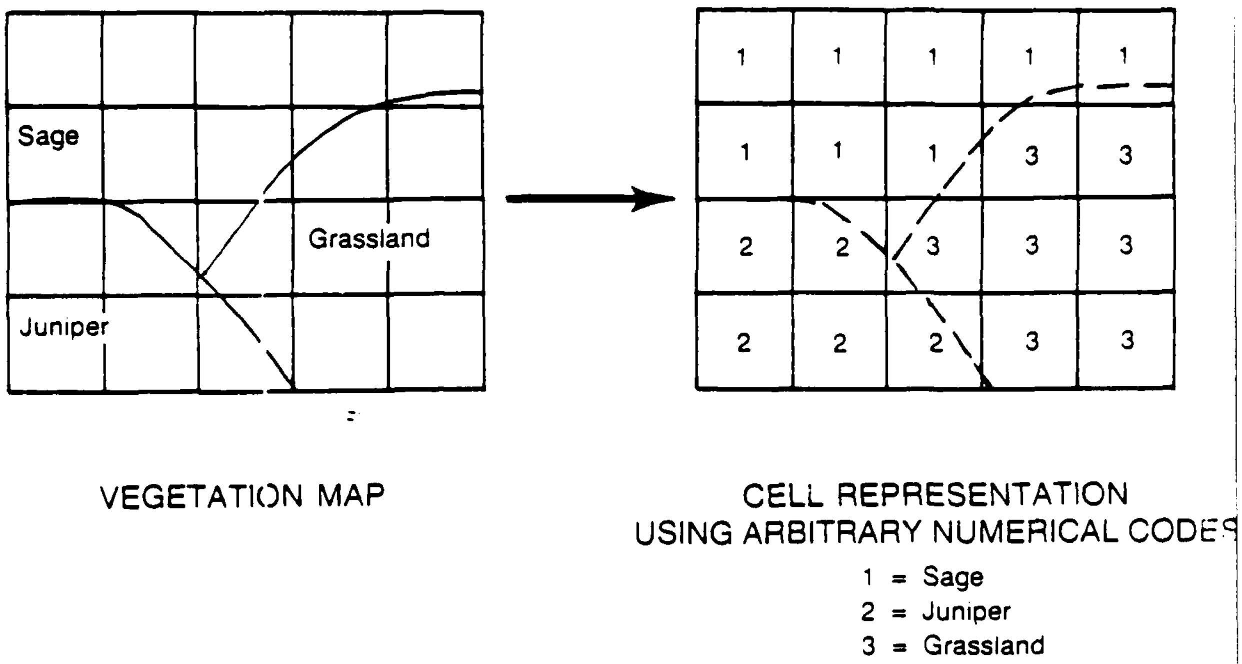
5.2 MOSS Commands

MOSS contains commands or key words that, when typed in at a computer terminal, perform some kind of operation. Most of the commands enable you to monitor, retrieve, or manipulate the data stored in MOSS data files. Other commands provide tutorial information on how to use MOSS and how to finish or compute the cost of a MOSS session.



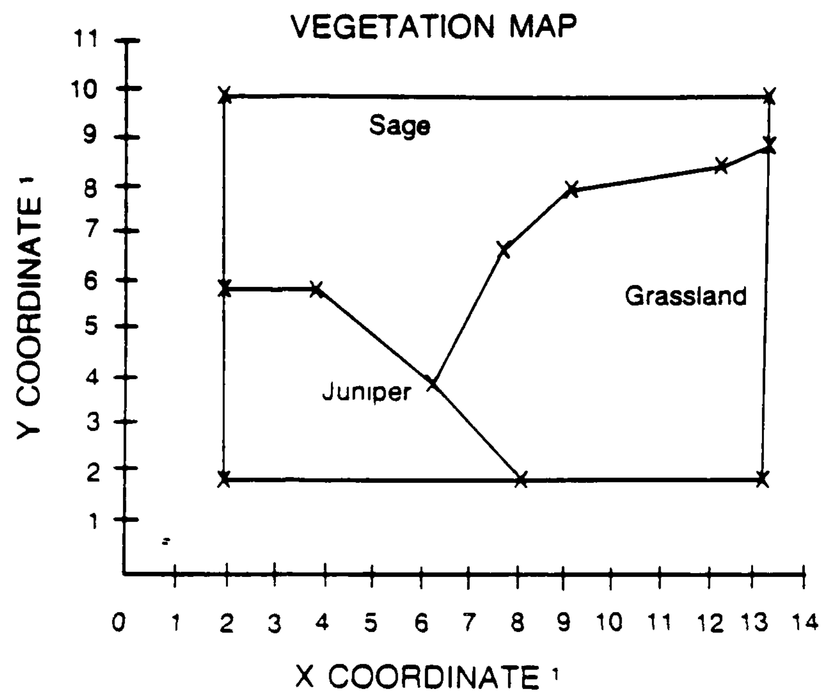
SOURCE: US F&W MOSS Users Manual.

FIGURE 9. The organization of MOSS data.



SOURCE: US F&W MOSS Users Manual.

FIGURE 10. An example of data stored in a grid cell format. The grid cell is user-specified.



[1] Universal Transverse Mercator

Sage Polygon Coordinates(X,Y)
(2,10) (13,10) (13,9) (12,8.5) (9,8) (7.5,7) (6,4) (4,6) (2,6) (2,10)

Juniper Polygon Coordinates (X,Y)
(2,2) (2,6) (4,6) (6,4) (8,2)

Grassland Polygon Coordinates (X,Y)
(8,2) (6,4) (7.5,7) (9,8) (8.5,12) (3,9) (13,2) (8,2)

SOURCE: US F&W MOSS Users Manual.

FIGURE 11. An example of data stored in polygon format.

After you have connected to MOSS, the system will automatically prompt you to

ENTER COMMAND

?

Whenever this message appears, MOSS is requesting you, the user, to type a command.

5.2.1 Command Options, Parameters, and Prompts

Command Options

Each command in MOSS represents a capability that can be used to process map data. The user executes a command by typing the name of the command followed by any options or parameters that are associated with the command. An option represents an alternative course of action that the user can take when executing a command. For example, the STATISTICS command has three options: CROSSTABS, HISTOGRAM, and DESCRIBE. In order to execute a command, the user must specify the option desired.

Command Parameters Specify Value or Name

While an option enables the user to choose a course of action, a parameter is a particular value or name that a user must provide. For example, to list the subject contained in a particular map, you must provide the name of the map. Similarly, to display a map, you must specify the ID number of the map from the active table.

Command Prompting

MOSS has been designed to prompt the user for the options and parameters associated with a command. The user simply has to type in the name of the command; MOSS will then query the user for both options and parameters that are required. For example,

```
ENTER COMMAND
? DISTANCE
ENTER AIRLINE OR PATH
? AIRLINE
POINT TO TWO LOCATIONS
```

In the above example, MOSS prompted the user to specify a particular option of the DISTANCE command.

Most of the MOSS commands have been designed to provide the capability to override some or all of the prompting messages. For example,

```
ENTER COMMAND
? DISTANCE AIRLINE
POINT TO TWO LOCATIONS
```

In the above example, both the command and the option were specified on a single line; one less step was required to execute the command. A few commands require that the option or parameter be entered with the command.

5.2.2 Entering Commands For A Typical MOSS Session

This section provides an overview of the general steps and associated commands that are common to most MOSS sessions.

Step 1—Connect to MOSS and MOSS Data

Once you log on under an account, type "MOSS," and then press the carriage return: MOSS starts executing. Then the user enters a name and carriage return to access MOSS commands.

Step 2—Browse the Data Base

The next step is to determine the type and the characteristics of the maps stored in the MOSS data files. This is accomplished with the LIST command. This step is analogous to using a card index file in a library for determining the kind of books and other information that the library contains. There are several options associated with the LIST command.

Example—Determining Map Names:

```
ENTER COMMAND
? LIST MAP

MASTER MAP FILES ARE
  WCOUNTY     WENERGY
  WSOILS      WANTELOP
CELL MAP FILES
  JOHCEL      SAGENED
POLYGON WORKFILE MAPS
  ANTELOPWIN
  ANTELOPSUM
```

In the above example, the MAP option of the LIST command was used to produce a list of the names of all the maps stored in both the master map file and work file(s) specified in Step 1.

The SUBJECTS and HEADER options of the LIST command are available to describe the characteristics and contents of these maps in detail.

The LIST command is important for two reasons: (1) to determine the suitability of any map for analysis, and (2) to provide a precise description of a map so that the user can specify to the computer the exact map or subset of a map that is needed. This point is especially important for Step 3 below.

Step 3—Activate Data

Before you can display or analyze any master file map or work file map, you must first activate the file map. This is accomplished by using the SELECT command. The SELECT command can be used at any point in a MOSS session to activate maps or subsets of maps. The only prerequisite to using the SELECT command is that the map name specified in the SELECT command must correspond exactly to the name listed in the master or work file. The name and subjects of any work file or master file map can be determined with the LIST command. An abbreviated or unprompted version of the SELECT command can be used to activate data in less time than otherwise would be required.

Example—Unprompted Select Command:

```
ENTER COMMAND
? SELECT WCOUNTY SUBJECT
ENTER SUBJECT SEARCH STRING?  SWEETWATER
SWEETWATER
NUMBER OF HITS = 1
```

In the above example, the subject SWEETWATER COUNTY was activated from the master file map name WCOUNTY. Note that any other subject containing the string SWEETWATER, e.g. SO SWEETWATER CR., would also be activated.

The ACTIVE command is available for monitoring the active data. The command

```
ENTER COMMAND
? ACTIVE
```

produces a table that describes each activated map. Information from this table is used in subsequent commands.

Step 4—Set the Display Window

Before any map data can be analyzed or displayed, you must set the display window. This is done as follows:

WINDOW 1

This will set the window to the first map the user selects.

Step 5—Redefine the Display Window

Frequently, only a certain portion of the study area is relevant to a user's problems. In these cases the ZOOM command resets the display window to enclose the specific area of interest. There are several advantages associated with ZOOM:

1. The display is magnified for greater detail.
2. Less data will be plotted on the CRT; thus the plot time is reduced.
3. The cost of executing MOSS commands is reduced, since the data outside the ZOOM area are not processed.

Step 6—Analyze, Display, or Create Spatial Subsets of the Data

Data that have been activated can be analyzed and displayed using a variety of analysis, display, and spatial retrieval commands. These commands perform various specialized functions. The specific command or sequence of commands to be used will depend on a specific problem being addressed. Section 4 describes the entire group of analysis, display, and retrieval commands that are available.

Step 7—Permanently Save Active File Maps

MOSS provides the capability to save any active map for future use. This capability is provided to reduce the time and cost of having to recreate a map at the start of each MOSS session.

Step 8—Finish the MOSS Session

At this point, you can either terminate the session or continue using MOSS by returning to any of the previous steps. The BYE command is used to terminate a MOSS session.

5.2.3 Description of MOSS Commands

Individually, each MOSS command offers a powerful capability to process digital map data. However, the full potential of MOSS can be realized only after the user understands (1) the full capabilities and limitations of each command, and (2) the added or synergistic capability that can be achieved by sequencing complementary commands. This portion illustrates the basic capabilities of MOSS. However, many of the commands are difficult to describe in an isolated manner. Only through frequent use and experimentation will the user realize the full potential of MOSS.

5.2.4 Groups of MOSS Commands

There are five functional groups of MOSS commands: (1) general purpose, (2) data base management, (3) spatial retrieval, (4) analysis, and (5) display commands. The following sections discuss the general capabilities and uses of each of the groups.

General Purpose Commands

The general purpose commands are a group of commands that perform a variety of unrelated functions. They provide the capability to (1) determine the geographic coordinates of any point on the CRT display screen, (2) identify an item on the CRT display screen, (3) terminate a MOSS run, (4) obtain assistance at any point during a session, (5) determine the cost of a session, (6) obtain information on any changes to the system, and (7) temporarily move out of MOSS and into the AOS Command Line Interpreter.

Data Base Management Commands

The data base management commands provide the capability to access and manipulate the map data base in MOSS. Specifically, the data base management commands can be used to (1) browse the contents of the data base at different levels of detail, (2) activate maps or portions of maps that are needed for analysis or display, (3) change the format of maps from polygon to cell, (4) save maps for future reference, (5) merge maps from adjoining areas into one map, and (6) create an independent data base for a study area whose boundary is user-specified.

MOSS provides a valuable tool to aid in browsing the data base and in activating maps for analysis. The Associated Attributes Data Base enables MOSS to store up to 200 discrete attributes, or descriptors, for any point, line, or polygon. These descriptors may be integer, real, or alphanumeric. This storage capability enables MOSS to handle such spatially referenced information as census data and forest inventory data. The associated attributes data base is easy to use and requires minimal training to understand and maintain.

General Structure of Attributes Data Base. Any attribute (synonymous with descriptor or variable) may be either integer (whole numbers), real, or alphanumeric (textual). If the attribute is integer, the allowable range of values is + 32767. If you desire numbers outside this range or that have textual data, such as a land use descriptor, then the alphanumeric type of storage would be used. Character strings may be up to 72 characters in length.

Any attribute in the attribute data base is composed of two logical parts—the header information and the data. The header information for an attribute, which is used as the basis for data base browsing and selection, has three key parts that must be understood by the user. The first part is the attribute I.D. The attribute I.D. is an integer number between 1 and 200. Each unique attribute will have one unique I.D. assigned to it. The second part is the key word. This is a 10 character or less key that can be used to quickly identify a particular attribute. For example, if you have a census variable median income, the key word in the data base might be MEDINCOME. No punctuation is allowed in the keyword. The third major part of the attribute header is a 60 character or less text description of what the attribute is.

Data Base Browsing. Data base browsing is the process of skimming through information about the maps in the data base to determine if any of the map data are of use for addressing your particular problem. This process is analogous to using a card catalogue in a library. In order to browse the attribute data base, you must type LIST (map name) ATTRIBUTE, where (map name) is the name of the map that you are interested in. Once entered, the LIST command will type a table. The first option will dump everything contained in a maps attribute data base, and therefore, should be used with discretion. Options 2, 3, and 4 enable you to look at the values for a given attribute in the attribute data base. Options 5, 6, and 7 print out information about the different attributes in the data base. Option 8 returns you to MOSS mainline.

Selecting From the Attribute Data Base. Once you have "browsed" through the attribute data base for a map and determined that it is the data you wanted, you can use the SELECT Command to activate data on the basis of the contents of the attribute data base. The form of SELECT command for doing this is SELECT (map name) ATTRIBUTE, where (map name) is the name of the map of interest.

5.2.5 Spatial Retrieval Commands

The spatial retrieval commands retrieve data from the MOSS data files based upon a spatial characteristic of the map data. The characteristics include (1) adjacent areas, (2) common boundaries, (3) distance from point or area, and (4) length or size.

5.2.6 **Analysis Commands**

The largest group of commands in MOSS is the analysis commands. In essence, the analysis commands provide the user with the capabilities to do something with the MOSS data.

There are three major types of analysis commands, **measurement**, **statistical**, and **synthesis**. **Measurement** commands facilitate the calculation of area, straight line distance, distance along an irregular line, and perimeters. **Statistical** commands are available to produce one- and two-way frequency tables; construct histograms; and calculate the mean, variance, and standard deviation of map variables. **Synthesis** commands are those that combine or manipulate several maps to create new or synthetic maps.

5.2.7 **Display Commands**

Display commands are available to display any map in MOSS on several output devices, including a graphics display (CRT) terminal, a plotter, and a line printer. These commands also provide the capability to display maps at any scale, place legends on maps, label map features, and graphically represent map features with different symbols. Depending on the analysis being performed, the user can select the most appropriate output medium.

5.3 Summary List of MOSS Commands by Group

Table 5-1 lists the MOSS commands by group: (1) general purpose, (2) data base management, (3) spatial retrieval, (4) analysis, and (5) display. This section is intended to provide users with a quick and ready-reference to each command's basic capabilities.

Table 5-1. Summary descriptions of the commands in MOSS.

Command name	Summary description
	GENERAL PURPOSE COMMANDS
CLI	Temporarily moves the user out of MOSS and into the AOS Command Line Interpreter. Refer to the AOS CLI Manual for further explanation.
COST	Summarizes the cost and computer time used in a MOSS session.
FINISH OR BYE	Terminates the MOSS session.
HELP	Produces a list of all MOSS commands or a detailed description of a particular command.
LOCATE	Determines the UTM coordinates of any point on a map.
NEWS	Produces a narrative description of recent changes to MOSS.
QUERY	Identifies the subject, area length, item number, map name, and category of any item displayed on a map.
	DATA BASE MANAGEMENT COMMANDS
ACTIVE	Produces a table identifying and describing the activated data.
ADD	Adds maps into the master data base.
ARCHIVE	Remove maps from the master data base onto tape.
AUDIT	Prints out a detailed summary of all items in a map.
DEARCHIVE	Removes maps from the archive tape and places them into the master data base.
DELETE	Deletes maps from the Master, Polygon, or Cell Directories.
DUMP	Outputs contents of a map to an external file. Used for debugging purposes. Should not be used by the general user.
EXPORT	Creates an ASCII text file in MOSS export import format.
FREE	"Deactivates" any active map (i.e., deletes any map referenced in the active map table).
LIST	Prints out the name, header, or subjects of the maps stored in the MOSS master file or work files.
MERGE	Combines maps referenced in the active map table into one map.
OPEN	Opens a file as an alternate master data base.

Command name	Summary description
	DATA BASE MANAGEMENT COMMANDS (continued)
POLYCELL	Converts any polygon, point, or line map into a cell map where the cell size is user-specified.
REPORT	Generates reports of the associated attributes data base.
SAVE	Saves any active data map as part of the user's work file.
SELECT	Activates all or a specific subset of any master file or work file map.
STATUS	Computes and prints out the number of items and coordinates pairs (X,Y) in a map; and the number of maps in master, polygon, and cell files.
STUDYAREA	Creates a spatial subset of the maps in the master file or work file for a user-specified study area.
TRANSLATE	Shifts or translates an entire active map in x and/or y.
	SPATIAL RETRIEVAL COMMANDS
CONTIGUITY	Activates all the polygons of subject type A and B, when A and B are adjacent to each other.
EDGE	Activates the edges or common boundaries shared by two or more subjects (e.g., the boundary between wetland and water).
PROXIMITY	Activates all the data from a map that are within a user-specified distance of some point or area or sets of points or areas.
SIZE	Activates polygons or lines from a map based on the size or length of the features on the map.
	ANALYSIS COMMANDS
AREA	Determines the area, frequency, and percentage of area of each subject in a polygon map.
BUFFER	Draws a buffer zone of user-specified size around any point, line, or polygon map.
DISTANCE	Measures the distance between any two points on a map, either along a path or "as the crow flies."
FREQUENCY	Determines the frequency and percentage of each subject in a map.
GRID	Interpolates elevation or point data onto a cell plane.
LENGTH	Determines the lentgh of all lines in any line map (e.g., a road map).
LPOVER	Performs an overlay of either a line or point map over a polygon map.

Command name	Summary description
	ANALYSIS COMMANDS (continued)
OVERLAY	Determines the logical intersection or union between any two polygon maps.
PERIMETER	Determines total length around polygons for the subjects in a polygon map.
POINTOVER	Enables overlay of a polygon map over a point map.
PROFILE	Generates a cross section diagram between two points using digital elevation data.
PROJECTION	Changes the projection type of an active data set.
SAMPLE	Performs a random sample of items in an active map.
SPSS	Prepares data for output to a file for later statistical analysis.
STATISTICS CROSSTABS	Produces a two-way frequency table of the contents of any two cell maps.
STATISTICS DESCRIBE	Produces summary statistics (i.e., variance, standard deviation, range, mean, etc.) on the area, length, or frequency of the subjects contained in a map.
STATISTICS HISTOGRAM	Produces a histogram or bar chart showing either the frequency, length, or area of each subject in a map.
WEED	Removes unneeded points from a line or polygon.
	DISPLAY COMMANDS
ASPECT	Converts digital elevation data to an aspect map.
BAUD	Enables the default baud rate to be changed for the terminal being used.
BLOWUP or ZOOM	Magnifies or enlarges a user-specified portion of the display window.
CALCOMP	Produces a data file for output on a Calcomp Pen Plotter.
CELLPLOT	Generates a cell map from cell data. The map is plotted to the Calcomp plotter.
CELLVERS	Generates a cell map from cell data. The map is plotted to the Versatec device.
CONTOUR	Produces a contour display of a gridded map.
DEVICE	Enables graphics output to be routed to a different device.

Command name	Summary description
	DISPLAY COMMANDS (continued)
ERASE	Erases all information displayed on the graphics display terminal (CRT).
LEGEND	Generates a map legend with scale, north arrow, title, and legend items; and labels map features on display.
LINE	Plots any line map (e.g., a road map) on the CRT using one of 30 possible symbols.
NUMBER	Enables the assignment of numbers to polygons in a map.
PLOT	Displays any active map on the CRT.
RESET	Sets the display window to the original coordinates specified by the WINDOW command (i.e., counteracts the BLOWUP command).
SHADE	Plots and shades any polygon map with cross-hatching on the CRT.
SLOPE	Converts digital terrain data to slope map.
SYMBOL	Plots any point map (e.g., the location of wells) on the CRT, using 1 of 20 possible symbols.
TESTGRID	Superimposes a cell grid of user-specified size over any map displayed on the CRT. TESTGRID is used to determine an appropriate cell size for converting a polygon map to a cell map.
THREED	Produces 3-D display of any raster map or digital terrain model.
WINDOW	Sets the display window to correspond to a particular area on the surface of the earth. This command is used to define the initial study area boundary.
WRITE	Generates files for output to devices external to MOSS.

NOTE: The commands listed above are subject to change as the software is improved and modified.

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